

## SPINAL IMPLANT ADJUSTMENT DEVICE

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### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

[0001] The present invention generally relates to a device for spinal fixation, and in particular to an adjustment device for many types of spinal implants. The device finds particularly suitable applications in spinal fusion devices such as a connector for coupling  
10 elongate members (such as spinal rods), plates, and the like, as well as in adjustable vertebral spacers for intervertebral fusion devices, corpectomy devices, and other vertebral prostheses.

#### 2. Background

15 [0002] The spinal column is a complex system of bones in stacked relation held upright by fibrous bands called ligaments and contractile elements called muscles. This column is critical for protecting the delicate spinal cord and nerves and for providing structural support for the entire body. There are seven bones in the neck (cervical) region, twelve bones in the chest (thoracic) region, and five bones in the low back (lumbar) region. There  
20 are also five bones in the pelvic (sacral) region which are normally fused together and form the back part of the pelvis. Each vertebra has a roughly cylindrical body with wing-like projections and a bony arch. The arches, which are positioned next to one another, create a tunnel-like space which houses the spinal cord. The anterior cylindrical bodies of the vertebrae, which are spaced apart by intervertebral discs, bear most of the compressive  
25 load of the spinal column. The spinal column is also flexible and is capable of a high degree of curvature and twist through a wide range of motion.

[0003] It is often necessary to surgically treat spinal disorders, such as scoliosis, as well as to surgically correct spinal problems such as those that occur due to trauma, developmental irregularities, or disease. Numerous systems are known for use in spinal  
30 correction and fixation, depending on the type of problem sought to be solved.

[0004] Spinal fusion (arthrodesis) devices attempt to restore stability to the spine by fusion in the problem area. These systems generally employ spinal instrumentation having connective structures such as one or more plates or rods that are placed on portions of the spinal column near the area intended to be fused. These systems usually include

attachment devices including, but not limited to, pedicle screws, transverse process hooks, sublaminar hooks, pedicle hooks, and other similar devices. Rod systems, of which there are several, are frequently used in spine stabilization. Typically, the rods are utilized in pairs longitudinally along the length of the spinal column. For the sake of simplicity, the  
5 term "rod" will be used throughout to refer to any elongate or longitudinal member.

[0005] It is known that the strength and stability of a dual rod assembly can be increased by coupling the two rods with a cross-brace or connector that extends substantially perpendicular to the longitudinal axes of the rods across the spine. The simplest situation in which a connector could be used occurs when the two rods are  
10 geometrically aligned. Specifically, the two rods are parallel to each other, that is, there is no rod convergence or divergence in the medial-lateral direction. Stated alternatively, the two rods have the same orientation with respect to the coronal plane (viewed in the anterior-posterior direction); or, the rods are coplanar from a lateral view; and the two rods are located a uniform distance from each other.

15 [0006] In reality, spinal rods are rarely geometrically aligned in the above-mentioned simplest situation. The actual variations of geometrical alignment must be accommodated in some fashion. One way to accommodate actual arrangement is for one or both of the rods to be bent to accommodate the connector. However, any bending in either of the rods can adversely affect the fixation to the spine and compromise clinical outcome.  
20 Furthermore, the bending can adversely affect the mechanical properties of the rods, not to mention the fact that bending is both difficult and time-consuming for the surgeon. The connector can also be bent so that the disturbance to the rod positioning is minimized. Unfortunately, this too can cause the mechanical properties of the connector to be compromised.

25 [0007] To remedy these concerns, connectors with some adjustability have been designed to adapt for variations from the simplest geometrical alignment. One major problem with current devices is that those that do provide some form of length adjustability utilize inferior locking designs. Some utilize a slideable member with a pin anchor. Others use a slideable member with a compression style lock. The former style is  
30 cumbersome and runs the risk of pin-removal. The latter style is cumbersome and provides inadequate locking strength. In fact, most require the surgeon to impart a large amount of force on the construct in order to engage the lock. Despite engagement of these locking devices, none of these types of locking devices has been shown to adequately positively lock the length.

[0008] Another major problem with the current devices is that the method of locking the rod to the connector is inefficient or inadequate. Many current devices utilize threaded set screws that engage an exterior surface of the rod. Threading the set screw into the set screw opening applies a compressive force on the rod, which is supposed to secure the rod.

5 Several problems exist with these threaded connections, including cross-threading, loosening over time, and the structural deformities imposed on the surface of the rod that is contacted by the set screw. Another current device uses a clamp body having opposable arms and utilizes a cam lug to force the arms closed in a scissors-like action to compressively load the rod. Yet another device utilizes a yoke-like clamping body  
10 disposed in a through-bore having resilient sidewalls that provide a wedging effect on the rod upon tightening of a locking screw in the through-bore. None of these devices, however, provide the simple, secure locking fit desired to positively retain a rod in situ long term.

[0009] An additional problem with these types of devices is that they are typically  
15 multi-piece systems that can be difficult to assemble and use in the surgical environment. And, even those that are one-piece designs do not allow for adjustments to compensate for all three modes in which there may be variation from geometrical alignment: convergence or divergence in the medial-lateral plane, non-coplanar rods, and variability in rod separation distances. For example, U.S. Pat. No. 5,947,966 discloses a device for linking  
20 adjacent spinal rods. In one embodiment, the device includes two members that are movable with respect to one another to accommodate different rod separation distances. A pin on one member engages a groove on the other member to provisionally couple the two members, thereby preventing a surgeon from separating the two members. Because the pin is sized to exactly fit the groove, no movement of the pin transverse to the longitudinal axis  
25 of the groove is possible. As a result, the device disclosed in the '966 patent cannot accommodate non-coplanar rods or adjust for rod convergence or divergence.

[0010] In some spinal surgeries, different types of devices are used to maintain the normal spacing between vertebrae, as well as to alleviate compression of the spinal cord. These devices are known as corpectomy devices and are typically inserted into a cavity  
30 created when all or a portion of one or more vertebrae are removed. One example of corpectomy devices are hollow mesh cages filled with bone chips or marrow, or even artificial bone material. Limitations of most present-day intervertebral implants are significant and revolve largely around the marked variation in disc space shape and height that results from either biologic variability or pathologic change. For example, if a disc

space is 20 mm in height, a cylindrical implant bridging this gap requires a minimum height of 20 mm just to contact the end plate of the vertebral bone. Generally, end plate disruption must occur to allow a generous bony union, meaning that an additional 2-3 mm must be added on each end, resulting in a final implant size of 24-26 mm. During

5 implantation from an anterior approach, excessive retraction is often required on the great blood vessels which significantly enhances the risk of devastating complications such as vascular tears or thrombosis. On the other hand, during a posterior approach, large implants may require excessive traction on neural elements for adequate placement, even if all posterior bony elements are removed. In some instances, an adequate implant size  
10 cannot be inserted posteriorly, particularly if there is a significant degree of ligamentous laxity requiring higher degrees of distraction to obtain stability by tightening the annular ligamentous tension band. Compromising on implant size risks sub-optimal stability or a loose implant, which has a greater chance for migration within or expulsion from the disc space. The alternative of excessively retracting neural elements to facilitate a posterior  
15 implant application results in a neuropraxia at best and permanent neural damage at worst.

[0011] Thus the need exists for an adjustable corpectomy that is simple to use in clinical procedures and that adequately and effectively spans the distance between vertebral bodies, is easily adjustable to account for space variability, and provides a secure lock once the desired dimension is achieved. Additionally, the need exists for an improved connector for  
20 spinal rods that can allow adjustability in all geometrical arrangements; that can provide quick and secure locking of the rod; and that provides a simple, positive locking length-adjusting mechanism that does not rely on compression fit or pin locking mechanisms.

## 25 BRIEF SUMMARY OF THE INVENTION

[0012] The present invention generally relates to devices for spinal fixation, and in particular to adjustable devices for use as connectors for coupling spinal rods or other elongate members; as well as for use as corpectomy devices and the like. Various embodiments are discussed, with the primary invention being utilized in different types of  
30 implants. As used herein, the general term "connector" shall refer to the device in its many embodiments, regardless whether the device is being used to connect elongate members (as in spinal rod systems) or to span the distance between two vertebral bodies (as in corpectomy devices). The connector generally comprises a two-piece body having an extending shaft and a housing; a rotor; and a locking collar. The terminal ends of each

connector may be fitted with a fixed rod-receiving jaw, an articulating rod-receiving jaw, or simply with endplates or other structures of various designs having bone receiving surfaces thereon.

[0013] In a first embodiment the extending shaft has an external surface containing thereon a helical profile. The rotor likewise has an internal surface containing thereon one or more helical surfaces that correspond to the external surface of the extending shaft. The internal helical surface of the rotor is placed in intimate contact with the external helical surface of an extending shaft. This intimate contact couples the rotor to the extending shaft such that translational movement of the extending shaft results in rotation of the rotor, and vice versa. Similarly, preventing movement of either the extending shaft or the rotor automatically prevents movement of the other.

[0014] The rotor is a substantially cylindrical body that has axial grooves disposed about its circumference. The locking collar is also a substantially cylindrical member having at least one protrusion disposed radially on the internal surface thereof. When the extending shaft is translated into or out of the body, the helical surface causes the rotor to spin inside the housing. When the desired length of the connector is achieved, the locking collar is moved from its unlocked position to its locked position, wherein the at least one protrusion engages the grooves on the rotor's circumference. Once a protrusion is inside a groove, rotational movement of the rotor is prevented, which thereby prevents axial movement of the extending shaft. This provides a positive lock for the extending shaft (and therefore for the length of the connector) without the need for a compression fit and without requiring the surgeon to impart large forces onto the construct.

[0015] In another aspect of the invention, a unique locking cam is provided at each jaw to secure a rod to the connector. The locking cam generally comprises a substantially cylindrical body having an engaging end and a driving end. The engaging end has a combination concave surface having differing curvatures disposed about its circumference, or simply having curvatures disposed at different points on the surface. The driving end has a cavity to receive a driving instrument and an appurtenant stop disposed at a location along its perimeter. The jaw comprises an opening to receive the locking cam therein. The opening is preferably substantially cylindrical having a discontinuity disposed out of phase with the appurtenant stop. Upon insertion of the cam into the opening, the driving instrument turns the cam the desired amount (preferably 180 degrees). This turning rotates the engaging end about the cam's axis of rotation, which brings the cam into tighter engagement with the rod as the combination curvatures rotate into engagement with the

outer surface of the rod. Once the cam is fully turned, the stop engages the discontinuity, which visually and tacitly informs the surgeon that the cam is locked.

[0016] In another aspect of the invention, an articulating jaw is provided. The articulating jaw itself comprises a jaw with a locking cam on one end and a ball-shaped protrusion on the other end. The terminal end of the connector comprises a substantially cylindrical member having an axial opening therein and comprising axial fingers for receiving the ball of an articulating jaw. The axial fingers are deflectable inwardly by a locking collar. The locking collar is disposed about the external surface of the fingers and is slideable between a first unlocked position and a second locked position. In the second position, the articulating jaw locking collar imparts a radial compressive force on the surface of the ball, thereby locking it into position. This can be achieved in various ways, including shaping the external surface of the fingers with an increasing diameter toward the distal ends thereof, such that as the articulating jaw locking collar moves distally, it rides along the increasing diameter, thus forcing the internal surface into compressive contact with the ball. Additionally the articulating locking collar itself may be fitted with an inner surface that has an increasing diameter in the locked direction. Many other structural combinations are possible to achieve this effect, the end result being to lock the ball in a given orientation. The articulating jaw can therefore assume any number of angles to better facilitate the rod.

[0017] The articulating jaw therefore forms a ball and socket joint that enables movement to allow the connector to join rods that are not parallel. Alternatively, the ball-shaped protrusion may be fitted on the body of the connector and the jaw may have the corresponding socket to provide the ball and socket union.

[0018] In another aspect of the invention, a fixed length connector is provided. The connector comprises a solid shaft with jaws on either end. The shaft is made from titanium or any material suitable for implantation. The jaws may be of the fixed or articulating variety as described.

[0019] In another embodiment of the invention the jaws comprise endplates or other structures to be used to engage vertebral bodies or other bony structures. The endplates can be fixed or variable to allow for better anatomical fit.

[0020] Alternative embodiments are also depicted utilizing pre-bent connectors; connectors utilizing multiple articulating jaws; connectors using grooved extending shafts; connectors using helical ratcheting shafts; connectors using a taper lock; and connectors utilizing a pivoting body.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0021] The teachings of the present invention can be readily understood by considering the following detailed description in conjunction with the accompanying drawings, in which:

[0022] Figure 1 is a perspective view of the apparatus according to one embodiment showing two connectors of the invention being used to connect two surgical rods secured to multiple bone anchors;

[0023] Figure 2 is a close-up perspective of a connector according to one embodiment wherein the connector further comprises an articulating jaw that is securing two non-parallel surgical rods;

[0024] Fig. 3 is a perspective view of a connector according to an embodiment of the invention having one fixed jaw and one articulating jaw;

[0025] Fig. 4 is a top plan view of the connector shown in Figure 3;

[0026] Fig. 5 is a side elevation view of the connector shown in Figure 3;

[0027] Fig. 6 is a section view in perspective of the connector according to an embodiment of the invention having a fixed jaw and an articulating jaw;

[0028] Fig. 7 is a perspective view of the two-piece body of a connector according to an embodiment of the invention;

[0029] Fig. 8 is a section view of the connector shown in Figure 7;

[0030] Fig. 9 is a side elevation view of the connector shown in Figure 7;

[0031] Fig. 10 is an end view of the connector shown in Figure 7 looking into the second axial opening;

[0032] Fig. 11 is a perspective view of a rotor according to an embodiment of the invention;

[0033] Fig. 12 is a side elevation view of the rotor shown in Figure 11;

[0034] Fig. 13 is an end view of the rotor shown in Figure 11;

[0035] Fig. 14 is a side elevation view in section of the rotor shown in Figure 11;

[0036] Fig. 15 is a sectional elevation view of a connector according to the invention having a fixed jaw (shown with a rod in the jaw and the cam in a locked position) and an articulating jaw (shown with the rod in the jaw and the cam in an unlocked position);

[0037] Fig. 16 is a perspective view of a locking collar according to an embodiment of the invention;

[0038] Fig. 17 is an end view of the locking collar shown in Figure 16;

[0039] Fig. 18 is a side elevation view of the locking collar shown in Figure 16;

[0040] Fig. 19 is a top plan view of the connector shown in Figure 2;

[0041] Fig. 20 is a partial top plan view of an articulating jaw of a connector according to one embodiment of the invention showing the locking cam in a locked position and the

5 articulating jaw in an unlocked position;

[0042] Fig. 21 is partial top plan view of the articulating jaw shown in Figure 20 showing the locking cam in an unlocked position and the articulating jaw in a locked position;

[0043] Fig. 22 is a perspective view of a locking cam according to an embodiment of  
10 the invention;

[0044] Fig. 23 is a driving end axial view of the locking cam of Figure 22;

[0045] Fig. 24 is a side elevation view of the locking cam of Figure 22;

[0046] Fig. 25 is a bottom elevation view of the locking cam of Figure 22;

[0047] Fig. 26 is an engaging end axial view of the locking cam of Figure 22;

15 [0048] Fig. 27 is a perspective view of a connector according to an alternative embodiment of the invention;

[0049] Fig. 28 is a top plan view of the connector shown in Figure 27;

[0050] Fig. 29 is a side elevation view of the connector shown in Figure 27;

[0051] Fig. 30 is an end elevation view of the connector shown in Figure 27;

20 [0052] Fig. 31 is a perspective view of an extending shaft according to an embodiment of the invention shown with a fixed jaw fitting;

[0053] Fig. 32 is a side elevation view of the extending shaft of Figure 31;

[0054] Fig. 33 is a top view of the extending shaft of Figure 31;

25 [0055] Fig. 34 is a side elevation cutaway view of the extending shaft shown in Figure 32;

[0056] Fig. 35 is an enlarged cutaway view of the radial opening and the axial opening of the body of a fixed jaw shown in Figure 34;

[0057] Fig. 36 is a top view of the radial opening shown in Figure 35;

30 [0058] Fig. 37 is a perspective view of an articulating jaw according to an embodiment of the invention;

[0059] Fig. 38 is a side elevation view of the articulating jaw shown in Figure 37;

[0060] Fig. 39 is a top view of the articulating jaw shown in Figure 37;

[0061] Fig. 40 is a side elevation cutaway view of the articulating jaw shown in Figure 38;



[0062] Fig. 41 is an enlarged cutaway view of the radial opening and the axial opening of the body of the articulating jaw shown in Figure 40;

[0063] Fig. 42 is a top view of the radial opening shown in Figure 41;

[0064] Fig. 43 is a perspective view of a retaining ring according to an embodiment of the invention;

[0065] Fig. 44 is an end elevation view of the retaining ring shown in Figure 43;

[0066] Fig. 45 is a perspective view of a connector according to an alternative embodiment wherein the housing and the extending shaft are bent;

[0067] Fig. 46 is a front elevation view of the connector shown in Figure 45;

[0068] Fig. 47 is a perspective view of a connector according to an alternative embodiment wherein the connector incorporates two articulating jaws;

[0069] Fig. 48 is a front elevation view of the connector shown in Figure 47;

[0070] Fig. 49 is a top view of the connector shown in Figure 47;

[0071] Fig. 50 is a partial perspective view of an alternative embodiment of the invention wherein the extending shaft has circumferential grooves, shown in an unlocked position;

[0072] Fig. 51 is a side elevation view of the connector shown in Figure 50;

[0073] Fig. 52 is a partial perspective view of the connector shown in Figure 50, shown in a locked position;

[0074] Fig. 53 is a side elevation view of the connector shown in Figure 52;

[0075] Fig. 54 is a partial perspective view of an alternative embodiment of the invention wherein the extending shaft has circumferential grooves but the shaft directly interfaces the locking collar, shown in an unlocked position;

[0076] Fig. 55 is a side elevation view of the connector shown in Figure 54;

[0077] Fig. 56 is a perspective view of the connector shown in Figure 54, shown in a locked position;

[0078] Fig. 57 is a side elevation view of the connector shown in Figure 56;

[0079] Fig. 58 is a perspective view of an alternative embodiment of the invention utilizing a portion of the housing to articulate;

[0080] Fig. 59 is a side elevation view of the connector shown in Figure 58;

[0081] Fig. 60 is a top view of the connector shown in Figure 58;

[0082] Fig. 61 is a perspective view of an alternative embodiment of the invention having two fixed jaws;

[0083] Fig. 62 is a side elevation view of the connector shown in Figure 61;

[0084] Fig. 63 is a top view of the connector shown in Figure 61;

[0085] Fig. 64 is a partial perspective view of an alternative embodiment of the invention utilizing a helical ratcheting extending shaft, shown in an unlocked position;

[0086] Fig. 65 is a side elevation view of the connector shown in Figure 64;

5 [0087] Fig. 66 is a partial perspective view of the connector shown in Figure 64, but shown in a locked position;

[0088] Fig. 67 is a side elevation view of the connector shown in Figure 66;

[0089] Fig. 68 is a partial perspective view of an alternative embodiment of the invention utilizing a taper lock;

10 [0090] Fig. 69 is a side elevation view of the connector shown in Figure 68;

[0091] Fig. 70 is a perspective view of an alternative embodiment of the invention employing a housing bent in multiple planes;

[0092] Fig. 71 is a side elevation view of the connector shown in Figure 70; and

[0093] Fig. 72 is a top view of the connector shown in Figure 70.

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#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

[0094] While the present invention will be described more fully hereinafter with reference to the accompanying drawings, in which particular embodiments and methods are shown, it is to be understood from the outset that persons of ordinary skill in the art  
20 may modify the invention herein described while achieving the functions and results of this invention. Accordingly, the description that follows is to be understood as illustrative and exemplary of specific embodiments within the broad scope of the present invention and not as limiting the scope of the invention. In the following descriptions, like numbers refer to similar features or like elements throughout. As stated before, the invention is usable in a  
25 variety of medical applications and indeed is not limited to spinal applications. The invention will be denoted as connector 10, it being understood that a variety of implant locations are possible. For ease of understanding, however, since spinal applications currently see great benefit from the invention, the following description is made with reference to spinal applications.

30 [0095] Figures 1, 2, and 19 show connectors 10 according to an embodiment of the invention in use as connectors to secure and connect two spinal rods 12. The connectors 10 can have fixed jaws 100, articulating jaws 200, or a combination of fixed and articulating jaws. The connectors 10 can thus accommodate rods 12 in any orientation and spatial arrangement.

[0096] Figures 3-6 show additional views of a connector 10 according to an embodiment of the invention. The connector 10 generally comprises a two-piece body having an extending shaft 20 and a housing 40; a rotor 60; and a locking collar 70. Each end of the connector 10 has a fitting 80 for engaging a structure (e.g., a rod 12, a vertebral body, and the like). In embodiments wherein the connector 10 is used to connect rods 12, the preferable fittings 80 comprise jaws 90 for engaging the rod 12. The jaws 90 can be in the form of a fixed jaw 100 or an articulating jaw 200, depending on the needs of the surgeon. Each fitting 80 includes a proximal end 81 and a distal end 82. The proximal end 81 preferably engages the connector 10 while the distal end 82 preferably engages other structures (for example, rods 12 in some embodiments or vertebral bodies in other embodiments, to name just a couple).

[0097] Figures 7-10 show a housing 40 of an adjustable embodiment for use with an articulating jaw 200. The housing 40 has a first portion 41 and a second portion 42 and preferably comprises two parts: a body 43 and a rotor 60. The first portion 41 preferably is attachable to an articulating jaw 200 (described below). The second portion 42 receives the extending shaft 20 (described below). The housing 40 is generally cylindrical with a first axial opening 44 therein for receiving the articulating jaw 200 and a second axial opening 45 therein for receiving the extending shaft 20. The rotor 60 is located in the second axial opening 45. The rotor 60 is generally cylindrical having an outer surface 61 and an inner surface 62. The inner surface 62 preferably contains one or more helical grooves 63 thereon so as to mate with corresponding helical grooves of the extending shaft 20. The outer surface 61 preferably contains circumferential grooves 64.

[0098] The second portion 42 preferably has a generally stepped cylindrical shape with a proximal end 46 having a first outer surface 48 and a distal end 47 having a second outer surface 49, wherein the second outer surface 49 has a diameter greater than that of the first outer surface 48. One or more slots 50 are formed in the first and second outer surfaces 48, 49. A ramping surface 51 provides a transition between the first outer surface 48 and the second outer surface 49. A lip 52 preferably is provided at the distal end of the ramping surface 51.

[0099] Referring to Figures 31-36, a typical extending shaft 20 is depicted. These figures show a fixed jaw 100 attached as the fitting 80, but recall that many types of fittings 80 are possible, including articulating jaws 200 (when used to connect rods 12) or other forms of endplates and so forth (when used as a corpectomy device). The extending shaft 20 has a first end 21 and a second end 22 wherein the first end 21 is insertable into

the second axial opening 45 of the second portion 42 and wherein the second end 22 is typically fitted with fitting 80. The extending shaft 20 has one or more helical grooves 23 disposed about its outer surface 24. A groove 25 is preferably located near the first end 21. This groove 25 will receive a retaining ring 26 (see Figures 43-44) which has a leading surface 27 and a trailing surface 28 and an inner diameter 29 and an outer diameter 30. As with many retaining rings, retaining ring 26 is resiliently expandable (such that inner diameter 29 and outer diameter 30 increase) so as to be fitted over the extending shaft 20 and moved to its residence in the groove 25, whereupon it contracts to its equilibrium dimensions. Similarly, the retaining ring 26 is resiliently contractible (such that inner diameter 29 and outer diameter 30 decrease) so as to be forcibly inserted into the second axial opening 45 past a structure that has an opening smaller than the outer diameter 30 (which could be a structure within the second portion 42 or which could be the inner surface 72 of the locking collar 70 (described below), as but two examples).

[00100] Referring to Figures 16-18, surrounding the body 43 is preferably a locking collar 70. The locking collar 70 is generally cylindrical in shape and comprises an outer surface 71 and an inner surface 72 and a proximal end 74 and a distal end 75. One or more protrusions 73 extend inwardly from the inner surface 72. The protrusions 73 are preferably stepped such that they have a first height 76 at the proximal end 74 and a second height 77 at the distal end 75, wherein the second height 77 is greater than the first height 76. The protrusions 73 reside in the slots 50, thus locating the locking collar 70 on the second portion 42 of the body 43. The locking collar 70 is slideable between a first unlocked position and a second locked position. In the first unlocked position, the locking collar 70 is located toward the proximal end 46 on the first outer surface 48 and the protrusions 73 do not engage the circumferential grooves 64 of the rotor 60. As the locking collar 70 is slid toward the distal end 47, the inner surface 72 of the locking collar 70 begins contacting the ramping surface 51. In the lock position the locking collar 70 passes over lip 52 and the inner surface 72 contacts the second outer surface 49. In this position, the second height 77 of the protrusions 73 engages one or more circumferential grooves 64 on the outer surface 61 of the rotor 60. In this position, the protrusions 73 prevent the rotor 60 from rotating about its axis.

[00101] With continuing reference to Figures 31-36, the fitting 80 is shown in this embodiment as a fixed jaw 100. The fixed jaw 100 shown here comprises a body 101 having a proximal end 102 and a distal end 103; an upper surface 104 and a lower surface 105; and a first side surface 106 and a second side surface 107. In the embodiment shown

for connecting rods 12, a rod opening 108 extends through the first and second side surfaces 106, 107 and is preferably open at the lower surface 105. The rod opening 108 forms an inner surface 109 that forms a partial cylindrical shape. The inner surface 109 has an axial opening 110 near the proximal end 102 for communication with a locking cam 90 (described below). The locking cam 90 is insertable in a radial opening 111 preferably located in the upper surface 104. The locking cam 90 is preferably retained in the radial opening 111 by a retaining ring 112 with structure and function similar to that of retaining ring 26.

[00102] Referring now to Figures 7-10 and 15, the first portion 41 is shown as attachable to a fitting 80 that takes the form of an articulating jaw 200. The first portion 41 preferably has a generally stepped open cylindrical shape with a proximal end 53 having a first outer surface 55 and a distal end 54 having a second outer surface 56, wherein the second outer surface 56 has a diameter greater than that of the first outer surface 55. Grooves 57 are formed in the distal end 54 at the first axial opening 44 so as to create resilient fingers 58. The resilient fingers 58 have an entrance diameter 58A and an internal opening 58B having a diameter 58C located a distance within the first portion 41, wherein the diameter 58C is greater than the entrance diameter 58A. A ramping surface 59 provides a transition between the first outer surface 55 and the second outer surface 56. A collar 199 having a generally open cylindrical shape has an outer surface 198 and an inner surface 197 and is assembled first to reside about the first outer surface 55 in an unlocked position. The collar 199 is slideable distally from the unlocked position to a locked position wherein the inner surface 197 surrounds the second outer surface 56. In this position, since the second outer surface 56 has a diameter greater than the first outer surface 55, the inner surface 197 of the locking collar 199, as it moves along ramping surface 59 and into the locking position, forces resilient fingers 58 to deflect inwardly. When a ball 213 (described below) is present within the internal opening 58B, this deflection locks the fingers 58 onto the outer surface of the ball 213, thus maintaining the articulating jaw 200 in a desired orientation.

[00103] Referring to Figures 37-42, a particular articulating jaw 200 is shown. The articulating jaw 200 has many of the same structures as that of the fixed jaw 100, and so the similar features will not be further described. These similar features include a body 201 having a proximal end 202 and a distal end 203; an upper surface 204 and a lower surface 205; a first side surface 206 and a second side surface 207; a rod opening 208; inner surface 209; axial opening 210; radial opening 211; and retaining ring 212.

Additionally, however, the articulating jaw 200 further comprises a ball 213 located at the proximal end 202. The ball 213 can take several shapes, including spherical and ovoidal, but is preferably spherical. The ball 213 has a diameter 214 that is preferably larger than the entrance diameter 58A and less than or equal to the diameter 58C.

5 [00104] Referring now to Figures 3, 4, 6, and 22-26, each jaw 90, whether fixed or articulating, preferably has a locking cam 91 for alternately engaging or disengaging a rod 12 therein. A particularly useful embodiment of a locking cam 91 is shown in Figures 22-26, though many other types of connectors or cams can be used. The locking cam 91 generally comprises an engaging end 92 and a driving end 93, wherein the engaging end 92  
10 is fitted with a complex curvate surface 94 having at least a first curvate surface 95 and a second curvate surface 96 such that in an unlocked position, the rod 12 can slide freely within the jaw 90, and in a locked position, the rod 12 is securely locked to the jaw 90 of the connector 10. The locking cam 91 can have a retaining mechanism 97 to keep the locking cam 91 in the jaw 90, such as a retaining ring that snaps into an undercut 98 in the  
15 jaw 90. Many embodiments of the engaging end of the locking cam 91 are possible to accomplish this. The embodiment shown in Figure 15 utilizes a complex curvature such that in section view—in an unlocked position (see the left jaw 90)—the first curvate surface 95 is located adjacent the rod 12, and the second curvate surface 96 is located away from the rod 12. The first curvate surface 95 may have a radius of curvature that is greater  
20 than that of the second curvate surface 96. Alternatively, the first curvate surface 95 may have the same radius of curvature as that of the second curvate surface 96 but may offset the origin of the curvature farther away from the centerline of the locking cam 91. Upon rotation of the locking cam 91 from the unlocked to the locked position (see the right jaw 91 shown in Figure 15), gradually the second curvate surface 96 is brought into contact  
25 with the rod 12, which wedges the rod 12 against the inner surface 109 within the jaw 90, thereby locking the rod 12 in position. This ability to draw the rod 12 up to the jaw 90 compensates for any misalignment between the opposing rods 12.

[00105] Figures 20-26 and 37-42 show one example of the visual and tactile feedback provided by the locking cams 91 of the invention on use with an articulating jaw 200. As  
30 stated above, the locking cam 91 generally comprises an engaging end 92 and a driving end 93. The driving end 93 is preferably circular in cross section and has a cavity 93A to receive a driving instrument (not shown) and an appurtenant stop 93B disposed at a location along its perimeter. The locking cam 91 is inserted into the radial opening 211 and is secured therein by a retaining mechanism 97. The radial opening 211 preferably

comprises a substantially circular opening having a discontinuity 211A disposed out of phase with the appurtenant stop 93B when in the unlocked position. A driving instrument turns the locking cam 91 the desired amount (preferably approximately 180 degrees). This turning rotates the engaging end 92 about the locking cam's 91 axis of rotation, which brings the second curvate surface 96 into contact with the rod 12, which wedges the rod 12 against the inner surface 209. When fully turned, the appurtenant stop 93B engages the discontinuity 211A, which visually and tactily informs the surgeon that the cam is locked.

[00106] Figures 27-30 show an alternative embodiment of a connector 10 of fixed length. Various sizes of such connectors 10 can be manufactured according to common lengths needed for patients of varying sizes and varying portions of the spine. In this embodiment, although no length adjusting mechanism as described above is present, the novel locking cam 91 structure to secure the rods 12 is present.

[00107] Figures 45 and 46 show an alternative embodiment of a connector 10 wherein the extending shaft 20 and the housing 40 are pre-bent to account for spinal curvature. Such embodiment can better reduce or eliminate interference of the connector 10 with vertebrae or other structures.

[00108] Figures 47-49 show an alternative embodiment of a connector 10 wherein the connector 10 contains two articulating jaws 200. Such embodiment is useful where the rods 12 are highly divergent. Without multiple articulating jaws 200, bending may be required for some connectors 10. This embodiment employs an articulating jaw 200 on both ends of the connector 10 to eliminate the need for any bending. It also enables better placement of the connector in vivo to avoid any interference from surrounding structures. The articulating jaw in the extending shaft 20 is similar in structure and function to that of the already described articulating jaw 200, providing means for rotating the jaw; locking it to the extending shaft 20; and telescoping the extending shaft 20 out of the housing 40.

[00109] Figures 50-53 show an alternative embodiment of a connector 10 wherein the extending shaft 20 comprises circumferential grooves 23A along the length thereof. The housing 40 has a corresponding ring 45A with grooves, for example within second axial opening 45, that will mate with the grooves 23A on the extending shaft 20. The extending shaft 20 moves relative to the housing 40, thus varying the overall length of the connector 20. The ring 45A is deflectable such that once the extending shaft 20 is in the proper place the housing 40 can be locked down onto the extending shaft 20 via a locking collar 70. The locking collar 70 is located preferably around the end of the housing 40 and locks the housing 40 on the extending shaft 20 by means of a cam feature or similar devices.

[00110] Figures 54-57 show an alternative embodiment to the circumferential groove device. In this embodiment, the locking collar 70 directly interfaces the extending shaft 20. The locking collar 70 has circumferential grooves 23A on its inner diameter or portions thereof. The locking collar 70 has an internal diameter that provides clearance to enable the extending shaft 20 to move axially relative to the housing 40. Conversely the extending shaft 20 has a portion thereof devoid of grooves to allow it to move freely relative to the locking collar 70. The locking collar 70 will be secured in place axially relative to the housing 40, but will be free to rotate a certain degree in order to interface with the extending shaft 20. When the desired length is reached the locking collar 70 can be turned a predetermined angle to engage the extending shaft 20. Other means of preventing the extending shaft 20 from rotating within the housing 40 are possible, including, but not limited to keys, pins, noncircular shaped second axial opening 45, and the like.

[00111] Figures 58-60 show an alternative embodiment of a connector 10 wherein instead of providing an articulating jaw 200, an articulating housing 40 is provided. Basically instead of employing the first axial opening 44 to receive the ball 213 of the articulating jaw 200, the first portion 41 of the housing 40 receives a ball. A locking mechanism can be incorporated into the connector 10 to permit the housing 40 to be fixed at a desired angle. The housing 40 preferably can pivot in all planes. Articulating jaws 200 as described above can be incorporated into this embodiment to allow for even more capability to interface with diverging rods.

[00112] Figures 61-63 show another alternative embodiment of a connector 10 wherein two fixed jaws 100 are in use. Any adjustments made to the connector to account for diverging rods 12 would have to be made by bending the connector 10 either at the extending shaft 20 or on the housing 40 itself. Bending could be made in any direction and would only be limited by the physical properties of the material.

[00113] Figures 64-67 show an alternative embodiment of a connector 10 having a ratcheting telescoping shaft 20. The shaft 20 contains helical grooves 23 similar to that previously described. The shaft 20 interfaces a rotor 60 that similarly has internal helical grooves 63 matching the external profile of the shaft 20. The rotor 60 likewise comprises circumferential grooves 64 or other indentations or extrusions on its external surface, again like that described above. A split ring 70A is provided that engages the circumferential grooves 64. The split ring 70A has engaging features on its internal surface which spring open when the circumferential grooves 64 rotate past them. This provides a ratcheting feel



to the telescoping of the shaft 20. The advantage is that a shaft 20 can be placed at a predetermined length before implantation and then small adjustments and locking could be made in vivo. Locking is accomplished by placing a ring, collar, or similar device onto the split ring 70A to prevent it from springing open. This in turn would prevent the rotor 60 from turning and the shaft 20 from translating.

[00114] Figures 68-69 show an alternative embodiment of a connector 10 utilizing a different means to lock the rotor 60. In this embodiment, a taper lock is used in place of the engaging features described above. The rotor 60 is cylindrical in shape but has a taper on the outer surface 61 in the direction of the rotational axis. A locking collar 70 has an inner surface 72 having a taper complementing that of the outer surface 61 of the rotor 60. The locking collar 70 resists rotation relative to the housing 40 thereby. Locking is accomplished by moving the locking collar 70 to interface the rotor 60 via the taper lock, thus preventing the rotor 60 from turning.

[00115] Figures 70-72 show an alternative embodiment of a connector 10 that is pre-bent in multiple planes. Any combination of bends in planes parallel to the rods 12, perpendicular to the rods 12, or in planes between the two are possible. This would account for any misalignment and divergence of the rods 12. The connector 10 is intended to accommodate rods 12 that are divergent and at different heights. This embodiment is a variation of the embodiment shown in Figures 45 and 46.

[00116] While there has been described and illustrated particular embodiments of a novel adjustable implant device, it will be apparent to those skilled in the art that variations and modifications may be possible without deviating from the broad spirit and principle of the present invention, which shall be limited solely by the scope of the claims appended hereto.